DEFECT DETECTION WITH AN ACTINIC DARK-FIELD MICROSCOPE

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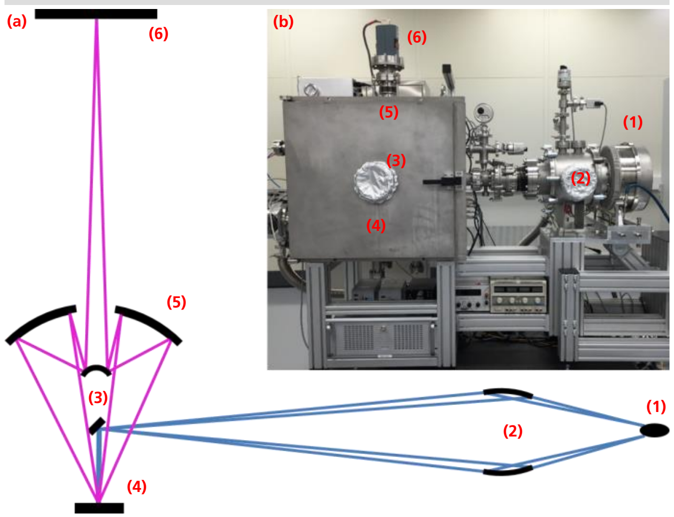
INTRODUCTION

The inspection of mask blanks is an important keystone of extreme ultraviolet lithography (EUVL). Top-level requirements for an industrial mask blank inspection tool are:

- sensitivity to buried defects of less than 30 nm in width and 1 nm in surface height,
- localizing defects with an accuracy below 10 nm and
- mapping all defects on the mask blank within 45 min.

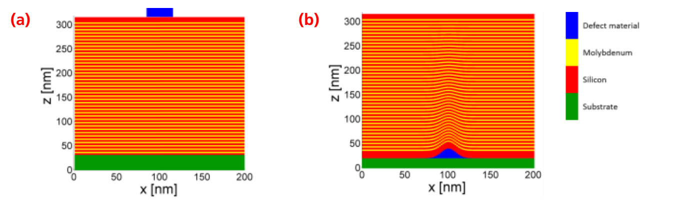
Currently, the repair strategy for mask blank absorber defects is based on a focused ion beam or electron beam removal technique, whereas defects inside the multilayer are coped with by making sure they are covered by absorber structures during mask manufacturing. Besides defect detection and localization, the distinction between the absorber and the multilayer defect type is mandatory for an inspection tool and has not been realized in one tool yet.

DARK-FIELD MICROSCOPY SETUP

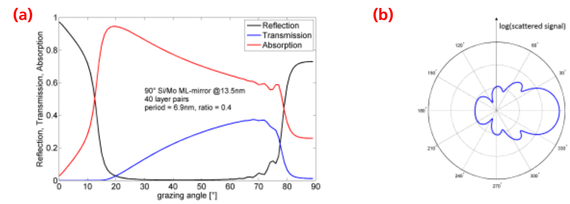


(a) Sketch and (b) photo of the EUV dark-field reflection microscope with (1) EUV source, (2) grazing incidence collector, (3) deflection mirror, (4) sample, (5) Schwarzschild objective and (6) CCD camera; The dark-field microscope is located in an ISO class 5 cleanroom. It is operated at a wavelength of 13.5 nm, has an objective magnification of 21 and a pixel resolution of 650 nm.

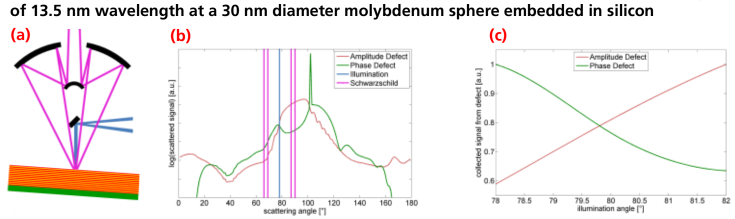
PHASE & AMPLITUDE DEFECT DISTINCTION

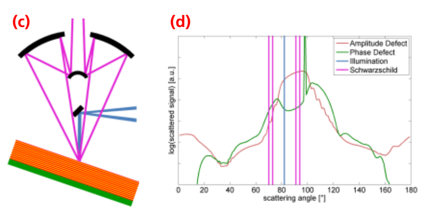


(a) Amplitude defect: an absorber defect on top of a multilayer structure (b) Phase defect: a defect inside of the multilayer structure that causes deformation of the layers



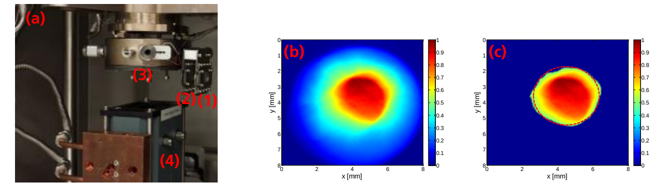
(a) Reflection, transmission and absorption curves of a Mo/Si multilayer mirror as a function of incidence angle for a wavelength of 13.5 nm and (b) logarithmic polar plot of Mie scattering of light of 13.5 nm wavelength at a 30 nm diameter molybdenum sphere embedded in silicon



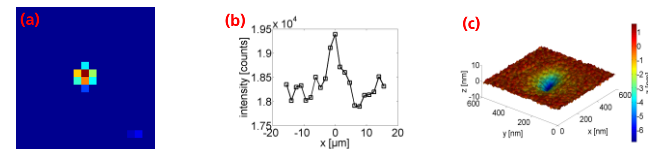


(a) Sketch of an 82° sample illumination for inspecting a defective multilayer structure and (b) respective defect scattering pattern; (c) illumination under 78° and (d) the respective defect scattering pattern; (e) normalized collected signal dependence of amplitude vs. phase defect as a function of the illumination angle; The curves show opposing behavior, thus a clear distinction between phase defects and amplitude defects can be made. The results were obtained with an analytical model that considers Mie scattering on top of/inside of a multilayer mirror.

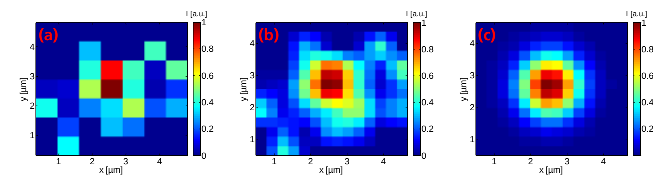
EXPERIMENTAL RESULTS



(a) Investigation of illumination spot size in the object plane: experimental setup with (1) intensity attenuator, (2) spectral filter, (3) deflection mirror and (4) in-vacuum CCD camera, additionally a shutter was installed in the beam path; (b) measured intensity distribution; (c) measured intensity inside FWHM together with an area equivalent circle of 2 mm diameter



(a) EUV reflection microscope image of a pit multilayer mirror surface defect; (b) cross section of the EUV image; (c) corresponding AFM image



(a) Mapping of a defect position: raw EUV microscope image of a defect, (b) interpolated raw image and (c) 2D-Gauss fit of the interpolated raw image. With that, the defect position can be determined with sub-pixel resolution

SUMMARY

- Proof of principle operation has been shown with the demonstrator
- Sensitivity to small defects has been shown
- Sub-pixel-resolution shows potential for precise defect localization
- Actinic (13.5 nm) mask blank inspection is sensitive to both, amplitude defects and phase defects
- An approach to experimentally distinguish between amplitude and phase defects by tilting a multilayer sample has been presented

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